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Bulk Handling and Quality Evaluation of POTATOES SHIPPED IN CONVEYORIZED RAILROAD CARS

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Prepared by

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in cooperation with

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BULK HANDLING AND QUALITY EVALUATION OF POTATOES SHIPPED IN CONVEYORIZED RAILROAD CARS

by Robert A. Ries and Harvey V. Toko[1/]

SUMMARY

Bulk shipments of potatoes in a rail car equipped with conveyors for loading and unloading offer an opportunity for labor and material savings and reduced shipping costs over the usual method of shipment in bags. Bruising from this method of handling potatoes was not excessive, and quality maintenance should compare favorably with other shipping methods. The bulk load also permits application of a gaseous sprout inhibitor after the loading is completed.

INTRODUCTION

Bulk shipment of potatoes by rail is not a new idea. In Maine, prior to 1924, loading was done by rolling barrels of potatoes into paper-lined boxcars and dumping them. As the cars filled, planks were placed on the pile so that additional barrels could be brought in. By the late 1920's the change to shipment in bags was made.[2/] This was done primarily to reduce the bruising of the potatoes inherent in the manual dumping process.

With the expansion of processing and the significant increase in the quantity of potatoes handled through terminal repack operations, there was a need for a bulk shipping method to replace the conventional bag system. To be successful, the new bulk method must provide more efficient handling during loading and unloading, with a minimum of bruising.[3/] For this purpose, a conveyorized, bulk potato car was developed by a Maine railroad. To evaluate this new concept of bulk handling, time studies were made on loading and unloading operations, and bruising of potatoes during loading, transit, and unloading was determined. Data were also obtained on temperatures in bulk cars during shipment and on the effects of a gaseous sprout inhibitor.

1/ Industrial engineer, Transportation and Facilities Research Division, and plant pathologist, Market Quality Research Division, Agricultural Research Service, respectively. Mr. Ries is deceased. Dr. Toko has transferred to the Forest Service, U.S. Department of Agriculture.

2/ Johnston, Edward F. Potato Production in Aroostook Has Increased Tenfold Since 1900. Potato Councilor Vol. 4, No. 11. November 1958.

3/ Perry, Alvah L., and Merchant, Charles H. Development of Defects in Potatoes Between Shipping Points in Aroostook County, Maine, and Wholesale and Retail Markets in Boston, Massachusetts. Maine Agr. Exp. Sta. Bul. 484, 35 pp. 1950.

DESCRIPTION OF BULK RAILROAD CAR

The bulk railroad car used in these tests was a railroad modification of an insulated boxcar (fig. 1). Potatoes brought through the car doorway are loaded into the car by two independently operated belt conveyors, one extending into each end of the car from the doorway. The conveyors are suspended from the ceiling by cables which permit them to be raised and lowered. A movable, padded plow is mounted on each conveyor to discharge the potatoes at any point for uniform distribution within the car (fig. 2).

Also installed in the car, at the floor, are fixed rod-chain conveyors, which extend from each end of the car to feed reversible, rod-chain cross conveyors between the doors, to accomplish unloading. Flow onto these conveyors is maintained by false plywood floors installed at an angle of 30° from the horizontal to form a hopper. Prior to loading, the conveyors are covered with boards to prevent potatoes from jamming between the rods and causing mechanical trouble and tuber bruising.

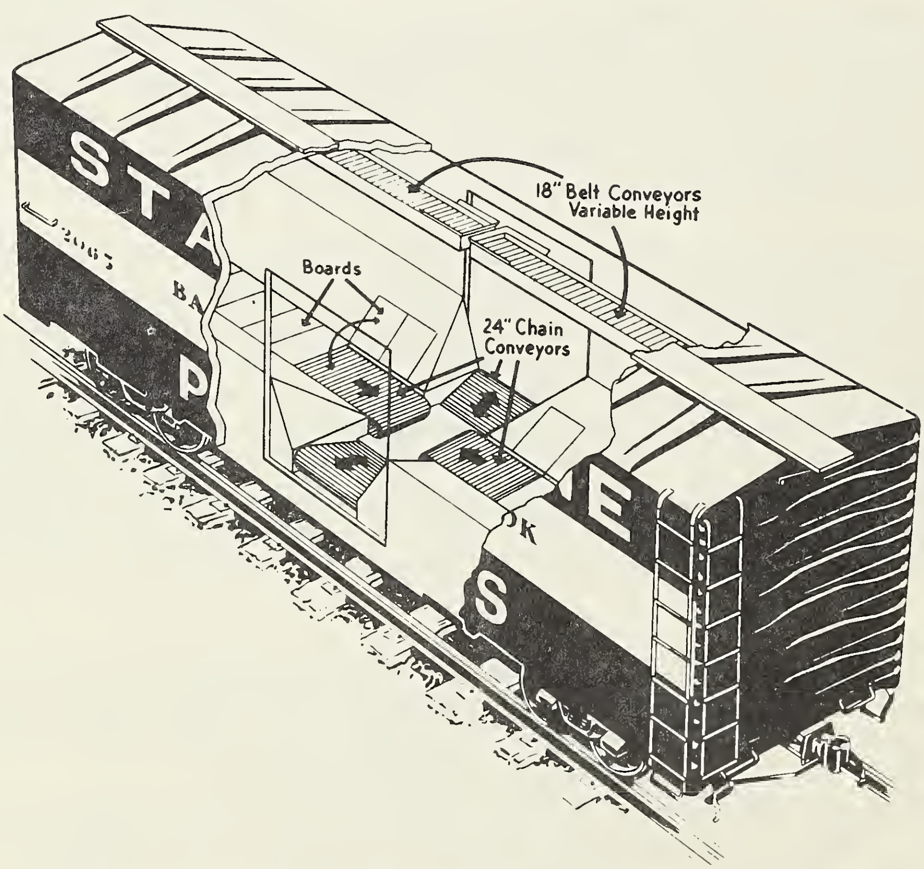

Figure 1.--Converted insulated boxcar.

Each door opening of the car has removable bulkhead boards. By opening a small, hinged gate in the bottom bulkhead board, movement of the load from the car is started by gravity (fig. 3). As the flow of potatoes continues, the boards covering the unloading conveyors become exposed. These boards

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Figure 2.--Loading conveyor and plow in operation.

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Figure 3.--Bulkhead gate is opened to start unloading.

are removed as unloading progresses to allow additional tubers to flow onto the conveyors. The boards are hung on hooks provided on the car wall. All conveyors, vertical positioning of loading conveyors, and movement of loading conveyor plows are electrically powered. A duplicate control panel located at each doorway permits complete operation from inside or outside the car.

HANDLING REQUIREMENTS

Loading

Loading the car requires an elevating, feeder conveyor capable of moving potatoes from the end of the packing line onto the loading conveyors in the car. This conveyor should be designed to permit easy shifting of position and have a low percentage of potatoes rolling back to the tail end when the conveyor is inclined to the maximum slope needed to place tubers on top of the load (fig. 4).

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Figure 4.--Type of feeder conveyor in use.

Two methods of loading are used. In one method, the potatoes are deposited in the car in layers using one loading conveyor at a time and raising it a few inches above each completed layer (fig. 5). This requires frequent shifts of the plow position to prevent burying the conveyor.

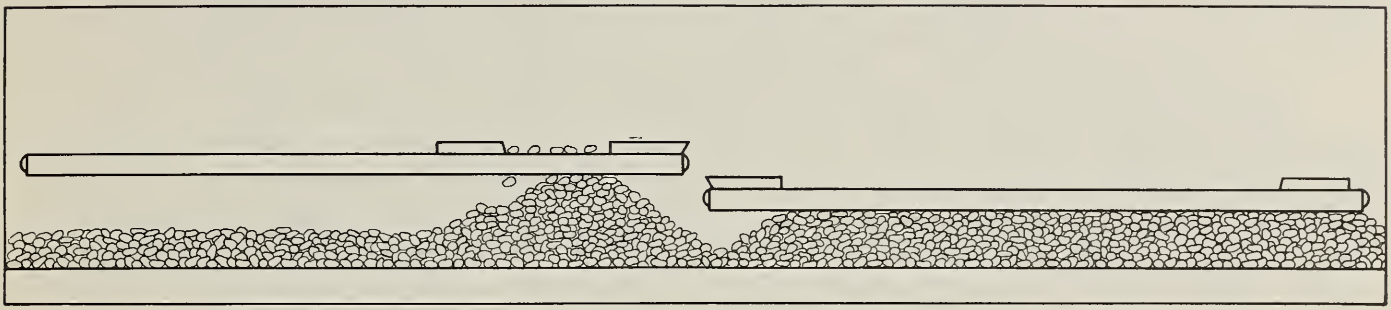

Figure 5.--Loading ends alternately, using layer method.

Another method consists of building piles near the doorway with both car conveyors operating simultaneously (fig. 6). This requires less attention by the man operating the car controls and permits him to do other intermittent work. Loading is continued by allowing the potatoes to roll down the faces of the piles until they build up to the conveyors. Shifting the plows back a few inches repeats this process. A final layer is placed on the pile in each end of the car separately, with the conveyor in the highest position to which the feeder conveying equipment can reach. With the ends filled, the car conveyors are raised to the ceiling and automatically latched. The doorway is then filled by use of the feeder conveyor alone.

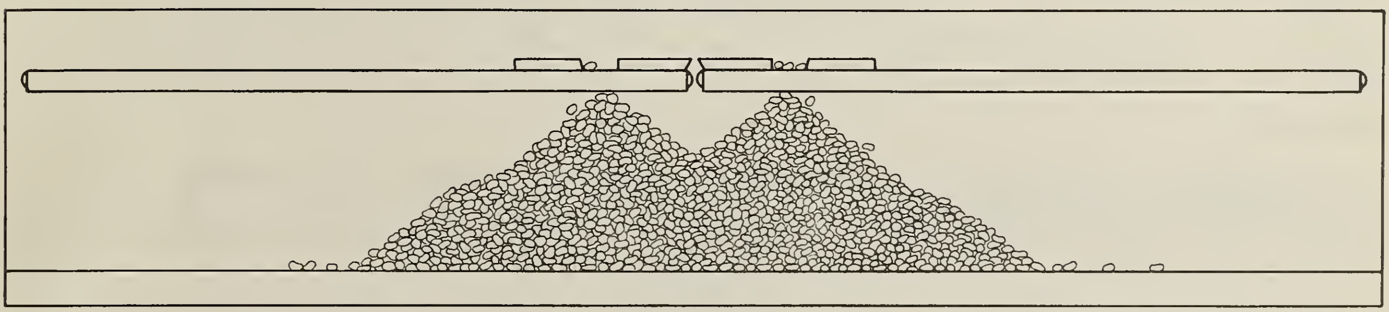

Figure 6.--Simultaneous loading of both ends of boxcar by pile method.

The loading conveyors in the car, if kept 75 percent filled, are each capable of handling 1,500 pounds per minute of operating time. At this flow rate, a car could be loaded with 72,000 pounds of potatoes (typical load of cars studied) in 48 minutes, plus average car-related delays of 21.6 minutes, or a total of 69.6 minutes. In actual practice, the loading time is limited by the capacity of the packing line and the supply rate. The average flow rate of the car loadings studied was 202 pounds per minute of operating time, keeping the car conveyors filled to only 10 percent of maximum capacity. This low utilization gave a loading time for 72,000 pounds of about 6 hours, plus delays. The overall time, including car and packing line delays, was 7.6 hours.

Direct labor savings using the bulk car instead of the bag-shipping method are shown in table 1. Only one worker is required to load the bulk car. The bag-filling method used for labor comparison consists of one man filling, one man closing, and one man trucking bags and stacking them in the car. A fourth man is used to help stack 100-pound bags in the car. Additional labor savings may be realized by better utilization of the supply and grading workers on the packing line when the flow-limiting bagging operation is removed. The amount of this saving depends on the line flow rate increase made possible by the change.

Table 1.--Packinghouse labor requirements to ship potatoes by bag and bulk car[1/]

Shipping method and number of workers	Operating time per cwt.	Labor required per cwt.	Labor saved with bulk car: Per cwt.	Labor saved with bulk car: Per 720 cwt.
	Minutes	Man-minutes	Man-minutes	Man-hours
50 lb. paper bag, 3 men	0.56	1.68	1.19	14.28
50 lb. burlap bag, 3 men	.74	2.22	1.73	20.76
100 lb. burlap bag, 4 men	.50	2.00	1.51	18.12
Bulk car, 1 man	.49	.49	----	-----

1/ Based on average observed packing line flow rate of 202 pounds per minute of operating time.

Unloading

The time and labor required to unload potatoes from the bulk rail car depend more on the operations at the receiving plant than on the unloading capacity of the car. For example, at a repacking plant, the receiving

operation must be related to the capacity of the packing line, and at a processing plant, to the capacity of the grading line where potatoes are filled into pallet boxes.

The receiving equipment used at repacking and processing plants is usually an elevating conveyor with a small hopper at the tail end. The hopper is necessary to prevent spillage of potatoes caused by the high flow rate of the car unloading conveyor.

At locations such as starch plants, where potato bruising is not a factor, a chute may be used to move potatoes directly from the unloading conveyors of the bulk car to cellar holding bins, and the full unloading capacity of the bulk car conveyors can be used. Here, the rate of flow would be 1,800 pounds of potatoes per operating minute. A comparison of unloading times at different types of receiving plants is given in table 2.

Table 2.--Observed times to unload 72,000 pounds of potatoes from the bulk car at three types of receiving plant

Type of receiving plant and destination of potatoes	Operating time 1/	Operating + car delay time 2/	Operating + car delay + flow regulation 3/	Overall time, including packing or grading line delay
	Minutes	Minutes	Minutes	Minutes
Repacking plant, direct flow to packing line --	113.8	120.2	131.8	201.6
Processor, direct flow to grading line for storage in pallet boxes	79.9	82.1	90.7	103.7
Starch plant, to cellar holding bin -----------	39.6	54.0	54.0	54.0

1/ Time during which potatoes were flowing from car.
2/ Delays inherent in the operation of the car unloading system.
3/ Unloading conveyors stopped to limit flow rate.

The unloading was done by one man in all cases. Where the receiving operation limited the flow rate, the operator's attention was directed chiefly to regulating the unloading rate to prevent overfilling the receiving equipment. Since the high-capacity unloading conveyors used in this car have no speed regulation, frequent stopping of the conveyors was necessary to maintain the desired flow. At the repack line, 54 stops per carload were made, and the processor's grading line required 85 stops for flow regulation.

SAVINGS IN SHIPPING AND MATERIALS COSTS

The freight rate per hundredweight (cwt.) is the same for bulk shipments as for 100-pound bags. However, for bulk shipment, the rate is applied on the basis of 680 cwt. per carload. The typical bulk carload is 720 cwt., so the bulk car permits shipping 40 cwt. at no extra cost. (The typical bag carload is 500 cwt.) The saving in freight charges for bulk shipments depends on the rate to the particular destination involved. For example, if the freight rate is 80 cents per cwt., the standard charge for 720 cwt. would be $576, but the charge for a bulk carload of 720 cwt. would be $544, or a saving of $32. For shipments within the lines of the originating railroad, there is an added charge of $20 per car, which would reduce the savings. The added charge is necessary because of the high investment in the special equipment and the relatively low rates for the shorter distances involved in within-line travel.

Elimination of bags is also an important cost reduction. The amount would vary with the type of bag used to ship potatoes and current prices. On the basis of 720 cwt., using 1964 prices, savings by eliminating bags would be:

100-pound burlap	$124.20
50-pound burlap	187.20
50-pound paper	91.22

QUALITY EVALUATION

Tuber Damage

To determine the amount of tuber damage in bulk car shipments, samples of potatoes were taken during loading and unloading of commercial shipments from Aroostook County, Maine, to North Kearny and Camden, N. J. Thirty samples, each consisting of approximately 10 pounds of potatoes, were selected at random from each carload.

At loading, samples were taken from floor level and at 18-, 24-, 36-, and 48-inch levels from only one end of the car in the 1960 preliminary tests and from both ends in the 1961 tests. Some samples were also collected from a conveyor at the end of the grading line in the 1960 preliminary tests. Because no apparent differences were found, samples were not collected from the conveyor in the 1961 tests.

At unloading, tuber samples were taken from the doorway area and one end of the car in the 1960 tests. This sampling procedure was modified for the 1961 tests to include at least 4 samples from the doorway area and 10 samples from each end of the rail car. In the 1961 tests, all samples were collected from the hopper of the unloading conveyor into which the tubers had dropped from the cross conveyor of the bulk car.

Samples were evaluated on the same day the tubers were collected. Each sample was weighed and all the tubers were examined individually for defects.

In the 1961 tests, each bruised tuber was cut and the defective portion weighed. A comparison was then made to the total weight of the tuber for determination of the bruise classification, based on U.S. grades. A minor bruise, therefore, was one which caused paring loss of less than 5 percent of the total weight of the tuber and, although not of commercial concern, was used for comparative purposes in these tests. Paring loss of more than 5 percent of the tuber was classified as a major bruise and is of commercial importance. The percentage of potatoes with pressure bruises, internal black spot, and rots was also determined. Pressure bruises in themselves are not considered defects. They are recorded here because internal black spot may develop beneath them during transit.

Considerable variation was found in the amount of fresh bruising which occurred at the shipping point. Samples taken during the loading of the bulk car shipments in 1960 showed one car to have only 0.6 percent major bruising in all samples, whereas the other car had more than 5 percent (table 3). However, at destination the difference in the amount of major bruising was only 2 percent. These variations may have been due to inadequate sampling or to variations in grading of the tubers by different individuals.

Table 3.--Percent of potatoes with minor and major bruises at shipping point and destination, 1960 preliminary tests

Shipment	Shipping point		Destination	
	Minor 1/	Major 2/	Minor 1/	Major 2/
	Percent	Percent	Percent	Percent
Car 1 -------	11.2	0.6	16.2	4.6
Car 2 -------	10.4	5.1	10.2	2.7

1/ Probably not of commercial importance; for comparative purposes only.
2/ Tubers having defective portion of more than 5 percent of the total weight.

In the 1961 shipping tests, much less variation in the amount of bruising was found at the shipping point. The incidence of minor bruising was, however, much more evident than in the earlier tests (table 4). This was probably due to the cooler tuber temperatures during these tests as compared with the 1960 tests (see discussion of transit temperatures in section following).

Table 4.--Percent of potatoes with minor bruises, rots, pressure bruises, and internal black spot, at shipping point and destination, 1961 bulk car shipments

Shipment	Point of evaluation	Bruises: Minor[1/]	Bruises: Major[2/]	Rots	Pressure bruises	Internal black spot: Slight	Internal black spot: Moderate
		Percent	Percent	Percent	Percent	Percent	Percent
Car 3 --	Shipping point	30.6	3.1	0.4	13.7	---	---
	Destination	24.8	6.7	.3	----	8.3	3.3
Car 4 --	Shipping point	25.0	3.9	.2	12.6	---	---
	Destination	26.1	4.9	.2	----	6.8	2.6
Car 5 --	Shipping point	16.7	4.8	---	7.0	---	---
	Destination	21.9	4.2	.2	----	4.1	---

1/ Probably not of commercial importance; for comparative purposes only.
2/ Tubers having defective portion more than 5 percent of the total weight.

The incidence of minor and major bruising was found to remain about the same or increase only slightly during transit in cars 4 and 5. However, in car 3, major bruising doubled between time of loading and unloading. Minor bruising in this car was found to be high at loading and considerably lower at unloading. This is a reversal of the results in the other test cars of this series. The great increase in major bruising may be attributed in part to the difficulty of determining the depth of the bruises at the loading point. Thus, some of the bruises originally classified as minor may in essence have been deep enough to have been of major proportion.

Severity of internal black spot at destination was related to amount of pressure bruising at shipping point. The method of shipment probably had no effect on internal black spot.

In addition to the overall classification of major and minor, bruises were further classified as to their probable point of occurrence. Thus, old bruises in which an apparently adequate suberin layer had developed were considered to have occurred some time prior to loading of the bulk car. Fresh bruises, in which the underlying tissue showed varying degrees of gray discoloration, were classed as having occurred either at loading or during transit. Fresh bruises with no tissue discoloration and usually showing evidence of moisture probably were the result of the unloading of the car.

Classification of bruises, based on their probable point of origin, is show in table 5. Although the use of a bruise classification based on color changes of the injured tissue has some disadvantage, i.e., degree of color change is dependent on temperature, the results indicate that relatively little major bruising occurred at the unloading point. The percentage of

total bruising was approximately the same for all cars in the 1961 tests. Considerable variation, however, was found in the amount of bruising that occurred at the time of loading, which corroborated observations made at the time the cars were loaded.

Table 5.--Percent of potatoes with minor and major bruises as related to probable point of origin of bruising, as determined in samples taken during unloading, 1961 bulk car shipments

Point of origin of bruising	Car 3		Car 4		Car 5	
	Minor bruises	Major bruises	Minor bruises	Major bruises	Minor bruises	Major bruises
	Percent	Percent	Percent	Percent	Percent	Percent
Prior to loading	12.6	2.0	10.3	2.0	13.9	2.6
At loading	9.0	3.7	12.3	1.1	4.2	.3
At unloading	3.3	1.0	3.5	1.9	3.8	1.3
Total bruising, 1/ all samples	24.8	6.7	26.1	4.9	21.9	4.2

1/ Total bruising percentage may vary from additive total due to conversion to the nearest tenth of a percentage point.

Transit Temperatures

The present bulk railroad cars are not provided with bunkers and, as a result, heaters or ice cannot be used inside the car for temperature control.[4] The commodity will thus be influenced by outside air temperatures. To determine the effect of outside air temperatures, recording thermometers were placed at various points within the bulk-loaded potatoes.

In the 1960 preliminary tests, thermometers were located at floor level and at the top level of the load--close to one end of the car. One thermometer was also located at the quarter length in the middle position of car 1, and in the top of the quarter length in car 2. In addition, outside air temperatures were recorded by a thermometer attached to the undercarriage of the rail car at center position.

In the 1961 tests, the thermometers within the load were located at the quarter length of cars 3, 4, and 5, at bottom, middle, and top positions. An outside air thermometer was used on only one car, since the three cars were shipped within a day of each other.

4/ The cars are equipped with underslung heaters which can be used, if necessary, to help warm the contents. The heaters were not used in the shipments discussed here.

During these test shipments, prolonged periods of extreme outside air temperatures were not experienced. The 1960 preliminary tests were conducted in May when temperatures were mild. During the transit period, outside temperatures ranged from 44° to 89° F. The tubers at the time of loading averaged 50° and 59° F., respectively, in cars 1 and 2. During the transit period, the air temperature within car 1 rose gradually from a low of 46° to 57° at floor level and at the top level, it increased from 52° to 65° F. In car 2, tuber temperatures averaged 59° F. at loading and gradually increased to a high of 73° F. The temperature increases and the level to which the increase occurred are probably a reflection of the increased average in outside temperature during the 2-week period between shipments.

The temperatures in cars 3, 4, and 5, which were cooler than temperatures in cars 1 and 2, can also be correlated with the outside air temperatures during the transit period. Cars 3, 4, and 5 were shipped on March 27 and 28, 1961; the outside temperature ranged from 29° to 65° F. Commodity temperatures at the time of loading averaged 42°, 42°, and 39° F., respectively, and increased only slightly, if at all, at the bottom quarter length position. The greatest temperature increase in these three test cars was 6° F.; this occurred at the upper level in car 3.

SPROUT INHIBITORS

To determine the effectiveness of a sprout inhibitor, CIPC, aerosol applications of this material were applied to potatoes in the two bulk rail cars shipped in 1960. The sprout inhibitor contained 16.66 percent CIPC plus 83.34 percent propellant. Treatment time was calculated on the basis of the bushel capacity of the entire internal volume of the rail car, plus the characteristics of the nozzle used to achieve the desired application rate of 1/2 gram of CIPC per bushel. Thus, the time of treatment was based on the actual volume of the rail car (3,280 cu. ft.), and not on the quantity of potatoes in the car at the time of treatment (about 66,000 pounds). By this method, treatment time was calculated to be 2 hours and 19 minutes.

The nozzle of the aerosol applicator was fixed above the tubers in such a manner as to prevent any direct spray of the sprout inhibitor onto the potatoes. Approximately one-half of the aerosol mixture was directed toward one end of the car (based on application time) and the remaining quantity was applied to the other end of the car.

Samples of potatoes were recovered from selected points at the time of unloading. All samples were returned to the Potato Handling Research Center, Presque Isle, Maine, and separated into two series. One series was submitted to a laboratory for residue analysis.[5] The second series (each sample weighed approximately 10 pounds) was held for a period of about 3 months at 50° F.

5/ Residue analyses were conducted by Chemical Division Laboratory, Pittsburg Plate Glass Company, Barberton, Ohio.

Upon removal of the samples from the 50° F. holding room, each tuber within a sample was examined individually for sprout activity. By using a sprout index rating of 1 to 5, with 1 indicating no evidence of sprout activity and 5 indicating sprouts that averaged more than an inch long, an average sprout index for the entire sample was calculated.

Little sprouting was found in most samples of tubers which had received a sprout inhibition treatment 3 months prior to examination (table 6). In the potatoes from car 1, the only visible sprouting was found in a sample from the B-end bottom. It is probable that poor air circulation at the time of treatment resulted in some dead air spaces and consequently tubers at this location had not received sufficient exposure to inhibit sprouting.

Table 6.--Residue analysis and sprouting index of potatoes treated with Chloro-IPC sprout inhibitor in bulk rail cars, 1960

Location of potatoes in rail car	Residue in p.p.m.		Sprout rating 1/ after 3 months storage at 50 F.	
	Car 1	Car 2	Car 1	Car 2
A-end top	0.5	86.8	1	1
A-end middle	.5	.5	1	2
A-end bottom	.5	.5	1	2
B-end top	2.8	about 1,200	1	1
B-end middle	.5	127.1	1	1
B-end bottom	.5	.5	4	1
Washed sample	.5	54.5	1	1
Check (not treated)	ND 2/	ND	5	3

1/ Rating of 1--no sprouts; 2--sprouts less than 1/4 inch long; 3--sprouts from 1/4 to 3/4 inch long; 4--sprouts from 3/4 to 1 inch long; 5--sprouts more than an inch long.
2/ Not determined.

The bulk cars used in these tests were not equipped with fans. In the second test car, an 8-inch fan was used to determine the effects of increased air circulation on the distribution of the sprout inhibitor. The fan was directed under the sloped floor to draw air away from the end of the car in which the sprout inhibitor was being applied. At the time the nozzle of the sprout inhibitor applicator was moved to the opposite end of the car, the fan was also moved.

After the application was completed, a shiny white residue was noted on the top tubers near the center of each end of the car. This residue had also been observed in earlier tests where application had been made to bulk potatoes in storage bins. Residues in these latter potatoes had been found to be only 15.4 p.p.m., so the crystallization observed in the tests of the bulk cars was not considered to be of any significance at the time. However,

the residue analysis of these samples showed an extremely high concentration of Chloro-IPC (table 6), greatly exceeding the tolerance of 50 p.p.m. No explanation for this accumulation of residues in the second test car could be determined. It is possible that use of the small fan may have caused a down-draft to be formed near the nozzle of the applicator, and thus the sprout inhibitor became concentrated at this point on the potatoes.

Sprout index readings of the samples from the second car indicated very good control of sprouting at all locations. The A-end middle and bottom samples showed some sprouting after the 3-month holding period, but the sprouts averaged only about one-quarter of an inch long.

Indications from these limited tests are that the application of gaseous sprout inhibitors to bulk rail car loads of potatoes may be practical. However, additional information on methods of application, with more uniform air circulation and, consequently, better sprout inhibitor distribution, is needed to reduce the possibility of accumulation of a high concentration of the materials in any given area of the potatoes being treated.

DISCUSSION

Bulk shipments of potatoes with the conveyorized railroad car show definite savings in shipping and materials costs and also require less labor to load than bag shipments. The advantages obtained will depend on the amount of use of the equipment and the investment required for special loading or unloading equipment.

Determining the weight of the load accurately has been a problem when shipping in bulk. Railroad scale weights are subject to variable quantities of ice and snow accumulation during the winter months--the peak shipping season. Use of an automatic batch weigher in the packing line will overcome this difficulty efficiently and give weight accuracy comparable to bag shipments. The automatic batch weigher also provides the shipper with continuous knowledge of the quantity of potatoes loaded.

Another method in use is a volume determination by the inspector. A series of measurements are made from the top of the load to the ceiling of the car to find the average height. The load, in barrels, is then determined from a table which was worked out by the railroad and the inspection service, based on 3.96 cubic feet per 165-pound barrel of potatoes.

Since the high capacity of the unloading conveyors causes difficulties in flow regulation at the receiving terminals, even with constant attention, consideration should be given to improvement at this point.

If the potatoes are to be washed in the operations immediately following unloading, they may be received into a tank of water with an elevator from the tank regulating the continuing flow rate. This would permit quick, gentle handling and good flow control.

When the potatoes must remain dry, a large hopper will provide better regulation than receiving directly onto a line-feeding conveyor. In most cases this should be above the dock level for simplicity of construction and fed by an elevating conveyor with a capacity equal to that of the car cross conveyor. A similar elevating conveyor would aid flow control when receiving into pallet boxes.

Handling of potatoes in bulk shipments probably does not increase the incidence of bruising any more than other methods of handling. The bruising that resulted at the time these test shipments were loaded and unloaded should be materially reduced as better handling equipment is developed.

The bulk method of shipping potatoes also affords an opportunity to use gaseous sprout inhibitors during late spring shipments. Some refinements of the method of application are necessary to achieve more even distribution of the inhibitor.

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